

### REMARKS

Claims 80-84, 88-110 are pending in the present application. Claims 80, 81, 84, 88, 89, 92, 95-101, and 104-110 are amended. In the Office Action dated October 19, 2004, the Examiner rejected claims 80 and 81 under 35 U.S.C. 103(a) as being unpatentable over Sun et al. (U.S. Patent No. 6,010,931) in view of Lu (U.S. Patent No. 6,017,818). Claims 82-84, and 88-110 were rejected under 35 U.S.C. 103(a) as being unpatentable over Sun et al. in view of Lu as applied to claim 80 above, and further in view of Yew et al. (U.S. Patent No. 6,114,200).

The embodiments disclosed in the present application will now be discussed in comparison to the cited references. Of course, the discussion of the disclosed embodiments, and the discussion of the differences between the disclosed embodiments and the cited references, do not define the scope or interpretation of any of the claims. Instead, such discussed differences merely help the Examiner appreciate important claim distinctions discussed thereafter.

Generally, a conductive layer is exposed to an oxygen-inhibiting plasma prior to the formation of another layer or layers on the conductive layer to substantially reduce the association of oxygen with the conductive layer during formation of the other layer or layers. By reducing the amount of oxygen associated with the conductive layer, the electrical characteristics of a semiconductor device including the conductive layer are improved.

Figures 4 and 5 illustrate in-process semiconductor devices being formed by a process according to one embodiment. As mentioned in the specification, for the purposes of explanation the in-process semiconductor device is assumed to be a capacitor in the process of being constructed. In Figure 4, the capacitor includes a first conductive layer 24, which may be formed from hemispherical silicon grain (HSG), formed over a substrate 22, and a dielectric 26 formed on the first conductive layer. In the examples of Figures 4 and 5, the dielectric 26 is formed from tantalum pentoxide Ta<sub>2</sub>O<sub>5</sub>. A second conductive layer 28 formed from tungsten nitride WN<sub>x</sub> is then formed on the dielectric 26. The tungsten nitride layer 28 has a tendency to associate with oxygen, particularly if that layer is exposed to oxygen prior to a third conductive polysilicon layer 30 being formed on the tungsten nitride layer 28. During subsequent processing of the capacitor, the oxygen contained in the tungsten nitride layer 28 can combine with silicon from the polysilicon layer 30 to form an unwanted silicon dioxide layer 36 between

the tungsten nitride layer 28 and the polysilicon layer 30. For example, a thermal process step such as the formation of a borophosphosilicate glass (BPSG) layer 34 over the polysilicon layer 30, which of course occurs after the formation of the polysilicon layer 30, may cause a reaction between the polysilicon layer 30 and the oxygen in the tungsten nitride layer 28 and thereby form the silicon dioxide layer 36.

The HSG layer 24 may form a first plate of the capacitor, the tantalum pentoxide 26 forms the dielectric of the capacitor, and the tungsten nitride layer 28 and polysilicon layer 30 form the second plate of the capacitor. With the formation of silicon dioxide layer 36, however, the capacitor now includes a first capacitor corresponding to the HSG layer 24, tantalum pentoxide 26, and tungsten nitride layer 28, and a second capacitor in series with the first capacitor, with the second capacitor corresponding to the tungsten nitride layer 28, silicon dioxide layer 36, and polysilicon layer 30. These first and second capacitors connected in series have a combined capacitance that is less than that of the ideally formed capacitor. As will be understood by those skilled in the art, the thickness of the silicon dioxide layer 36 affects the value of the combined capacitance.

In the capacitor of Figure 4, the thickness of the silicon dioxide layer 36 is greatly reduced by exposing the tungsten nitride layer 28 to an oxygen-inhibiting agent prior to the formation of the polysilicon layer 30 to thereby greatly reduce the association of the tungsten nitride layer with oxygen. The silicon dioxide layer 36 in the embodiment of Figure 4 is less than 10 angstroms thick due to the oxygen-inhibiting agent, while in a conventional capacitor shown in Figure 3 the silicon dioxide layer 36 is about 10-40 angstroms thick. In the capacitor of Figure 5, the exposure of the tungsten nitride layer 28 to the oxygen-inhibiting agent eliminates the formation of the silicon dioxide layer 36 altogether.

The oxygen-inhibiting agent may be an  $N_2$  and  $H_2$  plasma, with the tungsten nitride layer 28 ideally being exposed to this plasma prior to exposing tungsten nitride layer to an atmosphere associated with the formation of the polysilicon layer 30 or prior to exposing the tungsten nitride layer to oxygen. As described in the specification, it is believed the exposure of the tungsten nitride layer 28 to the  $N_2$  and  $H_2$  plasma or any of the other oxygen-inhibiting agents stuffs the tungsten nitride layer grain boundaries with nitrogen or otherwise passivates the tungsten nitride layer, making the bonds at the grain boundaries less active and less likely to

associate with oxygen. Additional gases include diborane and HCl. It should be noted that even if the tungsten nitride layer 28 is exposed to oxygen, the layer may thereafter be exposed to a reducing atmosphere, such as silane gas  $\text{SiH}_4$ , prior to formation of the polysilicon layer 30 to thereby reduce the oxygen content of the tungsten nitride layer 28 and reduce the thickness of any silicon dioxide layer 36 thereafter formed.

In another embodiment discussed with reference to Figure 6, a first conductive layer such as a tungsten nitride layer 128 is deposited over a substrate 122 and a dielectric layer 126, such as a tantalum pentoxide layer, is deposited over the tungsten nitride layer. In this situation, the deposition of the tantalum pentoxide layer 126 may cause the tungsten nitride layer 128 to incorporate oxygen, reducing the capacitance of a capacitor including the tungsten nitride layer and tantalum pentoxide layer. Accordingly, in this embodiment, the tungsten nitride layer 128 is exposed to a  $\text{N}_2$  and  $\text{H}_2$  plasma or other oxygen-inhibiting agent such as diborane or HCl before depositing the tantalum pentoxide layer 126. As previously described, the  $\text{N}_2$  and  $\text{H}_2$  plasma passivates the tungsten nitride layer 128 to thereby prevent oxygen from being incorporated within the tungsten nitride layer. Furthermore, the tungsten nitride layer 128 may be exposed to a reducing environment to reduce the oxygen content of the tungsten nitride layer 128. Additional embodiments are disclosed in Figures 7-10.

The Examiner has cited the Sun patent. The Sun patent discloses a capacitor structure having a lower electrode 98 formed of conventional polysilicon or hemispherical grained polysilicon (HSG). The lower electrode 98 can be formed by LPCVD of silane. A layer of dielectric 100 is then provided over the lower electrode 98 followed by providing an upper electrode 102 formed of doped polysilicon or titanium nitride thereover. The Sun patent does not disclose or fairly suggest exposing the upper electrode 102 formed of tungsten nitride with a material comprising HCl. In contrast, the Sun patent merely deposits another thick dielectric layer 110 over the upper electrode 102.

The Examiner has also cited the Lu patent. The Lu patent discloses a method of forming a tungsten nitride barrier layer. The barrier layer is formed by performing a MOCVD process to form a tungsten nitride layer. The as deposited layer is heated and then exposed while heating to pure or diluted silane, disilane, or  $\text{B}_2\text{H}_6$ . By exposing the layer to one of the aforementioned gases, the sheet resistance of the layer is reduced. However, the Lu patent does

not disclose or fairly suggest exposing the tungsten nitride layer to a material comprising HCl. In fact, the Lu patent makes no mention of reducing the ability of the tungsten nitride layer to associate with oxygen and, in fact, teaches away by disclosing that the tungsten nitride layer may be exposed to an oxygen atmosphere.

Turning now to the claims, the patentably distinct differences between the cited references and the claim language will be specifically pointed out. Claim 80 recites in part, “exposing the second conductive layer to a material comprising HCl,” the second conductive layer comprising tungsten nitride. As alluded to above, none of the cited references discloses exposing a tungsten nitride layer to a material comprising HCl.

Claim 81 recites in part, “exposing the first conductive layer to a material comprising HCl,” the first conductive layer comprising tungsten nitride. As alluded to above, none of the cited references discloses exposing a tungsten nitride layer to a material comprising HCl.

Claim 88 recites in part “passivating the second conductive layer by exposing the second conductive layer to a material comprising HCl,” the second conductive layer comprising tungsten nitride. As alluded to above, none of the cited references discloses exposing a tungsten nitride layer to a material comprising HCl.

Claim 89 recites in part “passivating the second conductive layer by exposing the first conductive layer to a material comprising HCl,” the first conductive layer comprising tungsten nitride. As alluded to above, none of the cited references discloses exposing a tungsten nitride layer to a material comprising HCl.

Claims depending from independent claims 80, 81, 88, and 89 are also allowable due to depending from an allowable base claim and further in view of the additional limitations recited in the dependent claims. Dependent claims 84, 92, 95-101, and 104-110 have been amended to provide consistency and a proper antecedent basis with their respective amended independent claims.

All of the claims remaining in the application (i.e., claims 80-84, 88-110) are now clearly allowable. Favorable consideration and a timely Notice of Allowance are earnestly solicited.

Respectfully submitted,

DORSEY & WHITNEY LLP



Marcus Simon  
Registration No. 50,258  
Telephone No. (206) 903-8787

MS:clr

Enclosures:

Postcard

Fee Transmittal Sheet (+ copy)

DORSEY & WHITNEY LLP  
1420 Fifth Avenue, Suite 3400  
Seattle, WA 98101-4010  
(206) 903-8800 (telephone)  
(206) 903-8820 (fax)

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